biological processes induced by radiation, e.g. with MRI. The most experience exists for in beam-PET. In Dresden, the current research focuses on time-resolved acquisition (4D-PET) and on automated detection of range deviations. In contrast, prompt gamma ray imaging is a relatively new and dynamic field of research. Several prompt γ-ray imaging detector systems are under development in various research centers around the world based on active- as well as passively collimated systems. A complementary approach, based on the time spectrum of the γ-ray emission, is investigated in Dresden. First promising results will be presented in the talk. However, so far there is no clinical application of prompt γ-ray based *in vivo* dosimetry. In contrast, radiation-induced biological changes have been used in clinical trials at the Massachusetts General Hospital in Boston (MGH) for range verification in both, spine and liver. A recent study, also carried out at MGH, aims at a better understanding of when those treatment related changes in the liver begin to appear.

Instead of assuring a safe and precise treatment by measuring the *in vivo* dose deposition, another approach is to decrease dose deposition uncertainties before beam delivery. This can be done in several ways: One approach tries to increase the robustness of the treatment plan against different types of uncertainties. This can be realized by including the robustness in the optimization and penalizing treatment plans with a dose deposition very prone to expected deviations. A completely different method for increasing dose deposition precision is based on online imaging during treatment: If the exact patient geometry would be known for every time point, the delivered dose deposition could be calculated and even adapted online if necessary. Online imaging could be performed with MRI scanners integrated in the treatment room in analogy to the combined MRI-linac approaches. At the moment this is a field of intense research with quite impressing progress.

At this point it is not clear which of the different methods to increase precision in particle therapy will find their way in routine clinical application. Nevertheless, the demand and the potential of these methods are unquestionable.

MONTE CARLO MODELING AND IMAGE-GUIDANCE IN PARTICLE THERAPY

G. Dedes, K. Parodi. *Department of Medical Physics, Ludwig Maximilians University, Munich, Germany*

The use of protons and heavier ions in external beam therapy offers distinctive advantages with respect to conventional radiotherapy using electromagnetic radiation. The physical selectivity of ions with the characteristic Bragg curve can enable high tumor-dose conformity, resulting in lower irradiation of healthy tissues and critical organs in close vicinity to the target volume. Moreover, the higher relative-biological-effectiveness (RBE), especially in the case of heavier ions, can offer improved control probability for radioresistant tumors. In this context, Monte Carlo (MC) particle transport and interaction methods are increasingly employed in clinical and research institutions as vital tools to support several aspects of beam modeling, treatment planning and quality assurance of high precision ion beam therapy.

This talk will review the role of MC methods in selected applications in particle therapy. Drawing on own experience at different European particle therapy facilities, the fine tuning of MC parameters for beam modeling will be presented. In addition, based on ongoing studies and collaborations, we will give an overview on the wide range of MC applications aiming at novel tools for image guidance and treatment planning. These include the support to the development of heavy ion and proton computed tomography, as well as the direct usage of MC-data in the inverse planning process, featuring calculations of both absorbed and biologically weighted dose. Development and validation of new solutions based on clinically established imaging modalities for adaptive strategies in particle therapy will be also addressed, together with research efforts to support unconventional imaging-based techniques detecting secondary radiation for in-vivo confirmation of the actual treatment delivery. Finally, the application of Monte Carlo tools in the emerging research area of laser driven ion acceleration for medical application will be briefly exposed.

Parts of this work have been supported by the DFG Cluster of Excellence MAP (Munich-Centre for Advanced Photonics), the DFG Project on Ion Radiography and Tomography, the FP7 Project ENVISION, and the BMBF Project SPARTA.

IMAGE GUIDANCE FOR ADAPTIVE RADIOTHERAPY: IS THERE STILL A NEED FOR SURROGATE SYSTEMS?

Torsten Moser. *Im Neuenheimer Feld 280, 69120, Heidelberg, Germany*

In conformal radiation therapy, accurate and reproducible patient setup is required. In this regard, initial setup errors, as well as day-to-day setup variation, still poses a clinically relevant problem. The available anatomic („internal") information of the patient, however, relies on the images of the planning CT, acquired up to weeks prior to treatment and does not reflect changes during the actual treatment. To correct in the actual situation, the most reliable information is obtained by 3D-imaging techniques like cone beam CT. Adaptive treatment techniques, moreover, adds a further component to the treatment chain, the feed-back. Again by daily image guidance, changes that occur during the treatment can be detected and handled. Meanwhile, most linear accelerators are able to acquire images (eg, kilovoltage/megavoltage setup images or cone beam computed tomography [CT] scans) that allow correlation of the actual patient position with that during treatment planning CT. By the use of such image guided radiation therapy techniques, the potential benefit for the patient has to be weighed against the additional risk associated with the imaging dose.

For this reason, non-radiologic techniques to verify the setup position of the patient are of great interest. As such developments, there are various systems available that provide also information of motion and/or position. There are devices available where electromagnetic markers have to be implanted into the patient or technologies where other information's are used to generate signals that can be used for position or motion correction. One of the latter are optical surface imaging systems. Optical surface imaging systems are able to reconstruct a 3-dimensional (3D) surface model relative to the isocenter position. A setup correction is calculated by registering actual images with reference images stored in the system beforehand. Although the technical accuracy of such systems has been shown to be quite high, their suitability for clinical application depends on additional aspects, in particular on a fixed spatial relation between the surface and target region. To analyze this, setup corrections from a surface imaging system were evaluated in 120 patients. As a measure of reliability, the corrections derived by the optical system were compared with those from 3D radiologic imaging, which is the current gold standard in image guided radiation therapy. We found a dependence on the target region and the used reference image modality. Therefore, additional radiologic imaging may still be necessary on a regular basis (e.g., weekly) or if the corrections of the optical system appear implausibly large. Nevertheless, such a combined application may help to reduce the imaging dose for the patient.

SMALL PHOTON FIELD DOSIMETRY: PRESENT STATUS

Maria M. Aspradakis. *Cantonal Hospital of Lucerne, 6000 Lucerne 16, Switzerland*

Background: IPEM report 103[1] summarised existing knowledge on the physics and challenges in the dosimetry of small MV photon fields, reviewed available detectors for dose measurement, gave recommendations based on existing knowledge and experience, explained the need of commissioning treatment planning systems for small field applications and pointed out directions for future work. This presentation reports on recent developments.

Materials and Methods: A megavoltage (MV) photon field is defined as 'small' when either the field size is not large enough to provide lateral charged particle equilibrium at the point of dose measurement or the collimating device obstructs part of the focal spot as viewed from that point. The overlapping penubras from opposing jaws result that the full width half maximum of the dose profile (FWHM) no longer matches the collimator setting. Thus, the conventional defintion of field size in terms of FWHM breaks down. The measurement of dosimetric paraments in such non-flat narrow fields becomes a challenge because most detectors are too large to resolve the non flat dose profile or that they perturb fluence in a